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Eco-Innovation: Applying the Woven Fabric from *Dendrocalamus asper* Fibers to Textile Product Design

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ABSTRACT

The objectives of this research were 1) to test the properties of the woven fabric from *Dendrocalamus asper (D.asper)* fiber blended with recycled polyester(r-PET), and 2) to study the design factors and evaluate the satisfaction with the new textile products. This is a mixed method research study, the results of which indicated that the physical properties of the developed textile fabric were assessed in accordance with textile testing standards, tensile strength, tear strength, fabric density, fabric weight, fabric thickness, abrasion resistance, and pilling resistance. The obtained fabric contained the unique textures of *D.asper* fiber blended with recycled polyester fibers. The population consisted of 3,012 visitors to Crafts Bangkok 2024 Thailand. The sample consisted of 353 visitors to Crafts Bangkok 2024 Thailand with an interest in textile products, obtained by simple random sampling with a 95% confidence level. Structured questionnaires with good quality (Cronbach's alpha = 0.919) were used as the research instrument. According to the exploratory factor analysis (EFA), there were four factors affecting consumers, i.e., 1) local materials, 2) green products, 3) healthiness, and 4) sustainability. Consumers had high levels of satisfaction with the new textile products ($\bar{x}$ = 4.235; S.D = 0.472). All four factors significantly affected consumer satisfaction ($p < .01$) and could predict the dependent variable at 84.7%, with the standardized regression equation: $Z = .196(X_1) + .394(X_2) + .244(X_3) + .307(X_4)$. The new textile products can therefore encourage the use of the abundantly available bamboo fibers in communities through sustainable development that helps increase economic value with eco-friendly qualities.

1. INTRODUCTION

Bamboo plants are popular in Thailand because they grow fast and can be easily grown. Thai people have preferred to eat bamboo shoots or to use the culms for home building from ancient times up until today. Bamboo has long been related to the culture and ways of life among Thai people, e.g., building bamboo homes, food from bamboo plants, and use of bamboo paper. The Thai government currently promotes bamboo cultivation to prevent soil erosion, and it is used for treatment of the soil for improved fertility. With better mechanical and biomass properties than other types of wood, bamboo is increasingly used as a key production material in the textile industry. Furthermore, because of its eco-friendly qualities and degradability in a short time, bamboo is suitable to be developed into fiber for future use in the eco-textile industry [1-4].

Dendrocalamus asper (*D. asper*) is a large and robust bamboo species that grows well in Southeast Asia. Its culms are strong and normally range from 8–20 cm., with a height between 20–30 m. In addition, the shoots can be eaten as a local food in Thailand [2]. *D. asper* contains the physical and morphological properties of its fiber, along with chemical compositions of the culms that can be processed into fiber that contains certain chemical compounds, i.e., holocellulose 70.83%±0.04, alpha-cellulose 67.26±0.51%, lignin 29.58 ±0.24%, and ash 1.73±0.03%. Therefore, *D. asper* fibers can be used in textile production [5]. Their specific gravity (SG) increases with the height of the culms, and *D. asper* fiber can bear high tensile pressure. When testing the mechanical properties of the internodes, their modulus of rupture (MOR) and modulus of elasticity (MOE) are high [1]. Moreover, *D. asper* also contains antibacterial and antifungal properties [6-9]. If *D. asper* fiber is used as a key material for mixing with fiber from polyethylene terephthalate (PET) wastes, it will be an additional method to reduce the use of natural resources and to promote reuse of plastic wastes or processing them for renewal of economic value.

Polyethylene terephthalate (PET) is a type of plastic that is widely used in markets [10]. Between 2020 and 2025 in the Asia-Pacific region, PET packaging has been used among 36.7% of consumers worldwide, resulting in a large amount of waste from PET. Therefore, the Thai government supports the recycling of PET packaging [11]. There have been several research studies revealing that almost all PET can be recycled or reused. It can also be processed into fiber for use in the textile industry, e.g., to produce carpet bases, sleeping bags, insulation materials, and clothing [12, 13].

Due to the antibacterial, antifungal, and antiviral properties of *D. asper* [3, 14] along with the properties of PET, the fiber of which is strong enough to be produced into textiles [15, 16]. To enhance yarn properties and reduce raw material costs, fiber blending is a common practice in the spinning industry. The blend ratios significantly influence various properties of the resulting yarn. Furthermore, the characteristics of blended yarns are affected by both the individual properties of the constituent fibers and their compatibility. Research has shown that stronger fibers must be incorporated at specified minimum proportions to achieve the desired tensile strength properties [17]. When both types of fibers are spun together, they create a new fiber with high tensile strength and antibacterial properties. This research implemented a research process that searched for the factors to design textile products from *D. asper* fiber blend with recycled polyester (r-PET) fiber for industrial production and the creation of textile products that lead to environmental sustainability and local economic growth.

2. LITERATURE REVIEW

At present, the world is focusing attention on the green economy in which manufacturers give precedence to reducing the environmental effects of their production processes. The textile industry is currently concerned about the development of fiber innovations that can be used in a sustainable and eco-textile industry [18]. Responsibility toward the environment can be demonstrated by processing a number of available natural materials into higher economic value. These are degradable materials, and this is thus regarded as a sustainable development guideline. Therefore, bamboo fibers are suitable for use because they are natural and local circular materials that can be easily found in local areas and provide several advantages, i.e., they are 1) low-cost, 2) lightweight, 3) circular, 4) biodegradable, and 5) renewable [19, 20]. Regarding development of materials from *D. asper* fiber, it is a highly efficient fiber that can be developed into textiles. It can also reduce imports of finished fibers from other countries, which will increase opportunities for competition in the Thai textile industry [21, 22]. Eco-fibers are usually called "sustainable yarns" as materials that are produced from nontoxic, circular, and degradable sources. For natural fibers mixed with other materials that can reduce environmental impacts, organic fibers and wastes can be processed together to create sustainable yarns with low environmental effects. These yarns are popular in the current textile industry [23, 24]. Recycled polyester from PET bottles is called r-PET. It can reduce the use of numerous types of polyester derived from pure petroleum [25]. Bamboo fibers and recycled polyester are widely used in textile industry because of their strength, durability, and low cost. They can also increase production capacity continuously and fiber sizes can be adjusted to be suitable for use [26-28].

Using eco-materials for textile product design is intended to reduce environmental impacts [19]. Developing textile innovations from *D. asper* fiber for processing into fiber for textile products is an approach that current entrepreneurs in the textile industry need to implement for development of their own products. Creating eco-innovations from *D. asper* fiber mixed with fiber from PET wastes conforms to the circular fashion model in accordance with the concept of circular economy with three goals, i.e., 1) to reduce waste from textile production processes, 2) to promote reuse, and 3) to implement ethical practices and create more sustainability for the world. These three goals are aimed at achievement of sustainability and eco-friendly qualities. The new fiber from this research contains properties of woven fabric in terms of strength, elasticity, and durability against mechanical properties. In this regard, testing the woven cloth from *D. asper* fiber mixed with recycled polyester from PET bottles would confirm the suitability of using this new woven cloth to be applied in accordance with international textile testing standards to create sustainable and eco-textile products. For the development of the fiber in this research, the methods included 1) analyzing and testing bamboo fiber for its antibacterial properties in accordance with textile standards, 2) assessing the physical properties of the cloth, and 3) studying the factors affecting textile product design from the new fiber obtained (Figure 1).

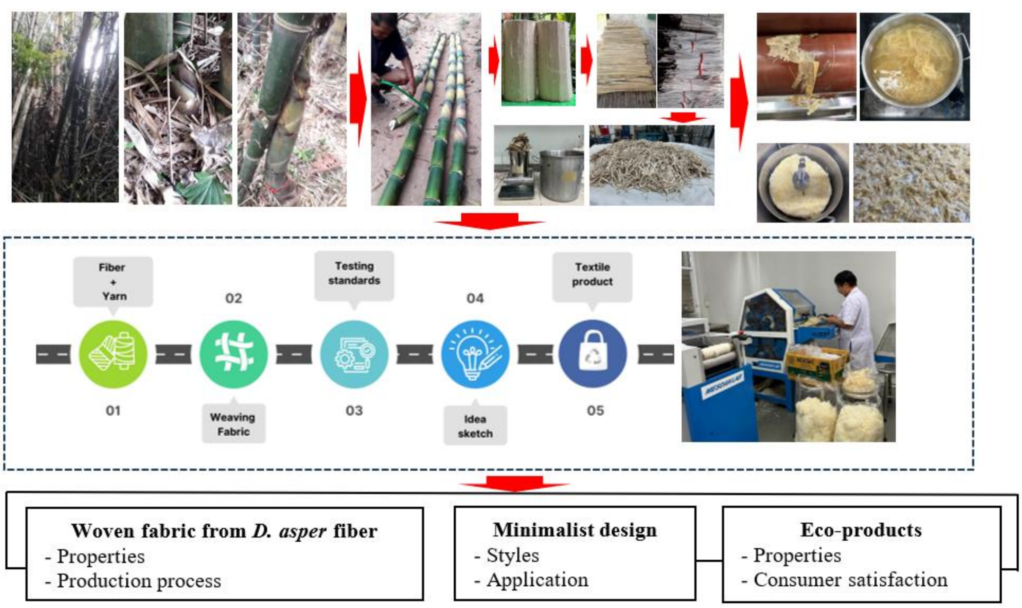


Figure 1. Conceptual framework

3. METHODOLOGY

This is a mixed method research study [29] with the following implementation steps, i.e., 1) studying the data, 2) testing, 3) identifying the design factors, 4) textile product design, and 5) evaluation of the results. The antibacterial properties of the woven fabric from *D. asper* fiber blended with r-PET were tested, and the risk factors affecting textile products from the newly developed fiber were analyzed by the following methods.

3.1 Research objectives

1) To test the properties of the woven fabric from *D. asper* fiber blended with r-PET.

2) To study the factors affecting the design of textile products from *D. asper* fiber blended with r-PET and to evaluate the satisfaction with these new textile products.

3.2 Testing the antibacterial properties of *D. asper* bamboo fibers

a) *D. asper* fiber separation: Fiber from 60-day-old *D. asper* in Roi Et Province was used. The fiber was separated by chemical and mechanical methods [30]. Antibacterial properties were tested under AATCC TM100-2019 (Antibacterial Finishes on Textile Materials), and gram-positive bacteria, i.e., *Staphylococcus aureus* (ATCC 3538), were used for testing.

b) Weaving the cloth from *D. asper* fiber blended with r-PET: To clarify, *D. asper* fiber and r-PET were spun and blended at the ratio of 30:70 (% by weight). They were spun into yarn by ring spinning, and then woven into cloth using air-jet weaving for the weft yarn while cotton was used as the warp yarn [31].

c) Assessing the physical properties of the cloth: The properties were tested as follows: 1) tensile strength was tested under ASTM D 2256-02 [31], 2) tear strength was tested under ISO 13937-1:2000 [32], 3) yarn density was tested under ISO7211/2:1984 [33], 4) fabric weight was tested under ASTM D3776/D3776M-09 [34], 5) fabric thickness was tested under ASTM D1777-96 [35], 6) abrasion resistance was tested under ISO 12947-2 [36], and 7) pilling resistance was tested under ASTM D 3512-99 [37].

3.3 Studying the factors affecting the design of textile products from *D. asper* fiber mixed with recycled polyester, and evaluating consumer satisfaction with the new textile products

a) Population: 2,504 visitors to OTOP Midyear 2024 at the IMPACT Exhibition and Convention Center, Muang Thong Thani, Thailand [38].

b) Sample: 345 visitors to OTOP Midyear 2024 at the IMPACT Exhibition and Convention Center, Muang Thong Thani, Thailand, obtained by stratified sampling [39] based on the divided zones in the center, with a total of six zones of Thailand's local product exhibition, with a 95% confidence level according to the Taro Yamane formula [40].

c) Instruments: Structured questionnaires were employed, consisting of 1) Questionnaire 1: Consumer needs for utilizing *D. asper* fiber for textile product design, and Questionnaire 2: Consumer satisfaction. The questions were designed as observed variables and could be measured as quantitative values. A 5-point Likert rating scale was used. The quality of Questionnaire 1 was good (IOC = 0.762; Cronbach's alpha = 0.919) in accordance with the criteria. The quality of Questionnaire 2 was also good (IOC = 0.640; Cronbach's alpha = 0.912) in accordance with the criteria [41, 42].

d) Data analysis: 1) mean, 2) standard deviation (S.D.), 3) exploratory factor analysis, and 4) multiple regression were used. All data were treated by SPSS [43].

e) The research was approved with regard to human ethics by the Institutional Review Board (IRB), King Mongkut's Institute of Technology Ladkrabang, according to the document no. EC-KMITL_67_012. The project was approved under serial no. 012/2024.

4. RESULTS

According to the test results of the antibacterial properties of 60-day-old *D. asper* fiber, i.e., obtained by testing the antibacterial properties using *Staphylococcus aureus,* a gram-positive bacteria that can be found on general fabrics and can cause infectious diseases of the skin [44], it was found that the fiber contained a low antibacterial property against *Staphylococcus aureus* (38.9%), as shown in Table 1. Also, it could not resist *Klebsiella pneumonia,* a gram-negative bacteria at all [45]. When compared with previous research using *D. asper* aged over 1 year under steam explosion to separate the fibers, it was found that the *D. asper* fiber obtained contained excellent antibacterial properties [46]. This research obtained the results of a low antibacterial property due to the use of young *D. asper* with low lignin. Furthermore, chemical extraction could eliminate a large amount of extractives and lignin, resulting in a lower antibacterial property as well as whiter and softer fibers. Studies [47, 48] have demonstrated that fiber preparation processes utilizing minimal or no chemical treatments are beneficial for maintaining antibacterial properties. Enzymatic fiber extraction has emerged as a promising process that warrants further investigation [49].

Due to the physical properties of yarn from bamboo fiber blended with r-PET by spinning these two types of fibers under the ratio of 30:70 by ring spinning [30], the yarn obtained possesses an exclusive texture. Because the bamboo fiber is larger than the r-PET, the texture of the yarn was rough because it was covered by bamboo fiber. Moreover, when the physical properties of yarn no. 10.4 were tested in the cotton count system (Ne), it contained tear strength at 15.67 newtons and elongation at break of 20.95% [30] as shown in Table 2.

Table 1. Antibacterial properties bamboo fiber

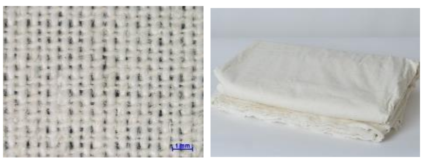
Antibacterial Finishes on Textile Materials: AATCC TM100-2019					
***Staphylococcus aureus* ATCC 6538 (CFU/SAMPLE)**			***Klebsiella pneumonia* ATCC 4352 (CFU/SAMPLE)**		
0 hour	24 hours	% reduction	0 hour	24 hours	% reduction
1.8×10^5	1.1 × 105	38.9	2.1×10^5	2.2 × 105	0.0

Table 2. Physical properties of the blended bamboo ring spinning yarn

Yarn Properties	Testing Results
Yarn no. (Ne)	10.4
Tear strength (N)	15.67
Elongation at break (%)	20.95

Regarding the physical properties of yarn from bamboo fiber blended with r-PET by blended *D. asper* yarn with r-PET size 10/1 in the cotton count system (Ne) as the weft yarn, along with cotton yarn size 32/2 as the warp yarn in the cotton count system (Ne), both types of yarns were woven into the cloth by air-jet. Because the warp yarn was smaller than the weft yarn, the features of the weft were prominent, and because it was larger, it could cover the fabric surface efficiently, as shown in Table 3.

Table 3. The fabric structure was woven with bamboo fiber blended with r-PET (microscope scan, 10× magnification)

Description	Fabric Structure
warp yarn: cotton yarn 32/2 Ne **weft yarn:** bamboo fiber blended with r-PET 10/1 Ne **yarn density:** 70 × 65 threads/inch	

Regarding the tested physical properties of the yarn from bamboo fiber blended with r-PET, when the new woven fabric was analyzed for its quality, the tensile strength of the weft and warp yarns was equal to 473.8 and 1896.4, respectively, and the elongation of the weft and warp yarns was equal to 20.7% and 23.0%, respectively. Their tear strength was equal to 24.3% and 15.8 newtons, respectively. The fabric density of the weft and warp yarns was equal to 70 threads/inch and 65 threads/inch, respectively. Fabric thickness was equal to 0.286 mm., previous study [30] categorized as medium fabric thicknesses [50]. In general, fabrics are categorized into three types according to their thickness, i.e., 1) thin fabrics < 0.20 mm., 2) medium-thick fabrics between 0.23–0.46 mm., and 3) very thick fabrics > 0.47. Fabric weight was equal to 193.5 g/m^2, categorized into medium-weight fabrics [50].

Likewise, fabrics are generally categorized into five types by weight, i.e., 1) very light fabrics < 35 g/m^2, 2) light fabrics between 70–100 g/m^2, 3) medium-weight fabrics between 170–240 g/m^2, 4) fabrics with weight between 300–375 g/m^2, and 5) heavy-weight fabrics > 475 g/m^2. The woven fabric obtained contained more warp yarn than weft yarn because the first element was smaller than the latter one, resulting in a lower number of pieces per square inch. That was because its large size caused the rough texture of the fabric due to the weft yarn covering the warp. As a result, the color and texture of the woven fabric are unique.

For the effects of abrasion on the woven fabric from bamboo fiber blended with r-PET fibers according to the abrasion resistance testing, it was found that the fabric's roughness was affected by abrasion. The amount of fiber pulled from the fabric texture increased when the abrasion was increased to over 10,000 cycles. There was a large amount of weft yarn appearing on the fibers as shown in Figure 2.

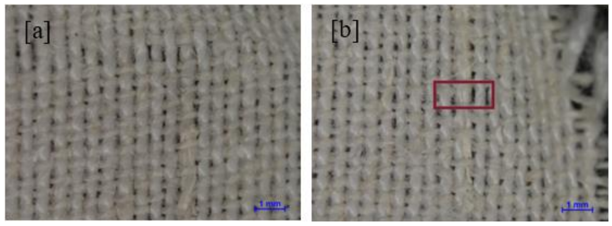


Figure 2. Photos of woven fabric from bamboo fiber mixed with recycled polyester: (a) before abrasion, (b) after 10,000 abrasion cycles (microscope scan, 10× magnification)

For the effects of pilling on the bamboo fiber woven fabric blended with r-PET fibers according to the testing, as shown in Figure 3, medium pilling was found (level 3). When the fabric was used, it revealed pilling resistance. Therefore, it is suitable for the production of clothes, bags, and shoes, which should possess pilling resistance.

Figure 3. Photos of pilling formation on woven fabric from bamboo fiber blended with recycled polyester after 30 minutes

For the study results of the factors affecting the textile product design and consumer satisfaction, it was found that consumer needs for utilizing *D. asper* fiber for eco-textile product design should consider the factors in the design steps, divided into two parts as follows.

Step 1: Exploratory factor analysis (EFA) – All data underwent variable categorization by EFA. Data on consumer needs was collected to identify the variables affecting the needs related to utilization of *D. asper* fiber for eco-textile product design and consumer satisfaction. This was conducted to survey the variables and to specify the common factors in order to explain the relationships of all variables. The indicators were examined by 1) agreements and 2) the testing of the relationships and variable categorization [43].

1) Data verification was divided into four steps, i.e., 1) setting 22 variables, 2) setting the sample at a minimum of 345 participants [43], and 3) verifying the communality of each factor that could explain the factors, which should be > .61.

2) Based on the results of the data verification, it was found that the communalities of all factors were between .878–.610 (> .61). Clustering of the factors was found, which led to the explanations of the factors related to consumer needs for eco-textile products. KMO and Bartlett's Test was equal to .827 (> .51).

3) Following analysis of the data collected from consumers for data categorization by surveying consumer satisfaction and needs and identifying the variables affecting purchase decision and satisfaction, the results were as follows.

KMO = .827 (> 0.50). All collected data revealed the perspectives on consumer needs regarding eco-textile products and could be processed using EFA (Chi-Square = 4793.756; df = 231) with statistical significance (Sig. = .000). The relationships between all variables were found, as seen in Table 4.

As shown in Table 5, there were 22 variables that could be categorized into four factors, with loading from high to low respectively as follows. Factor 1 was required the most, which could explain a variance at 40.002; followed by Factor 2 at 8.417, Factor 3 at 6.202, and Factor 4 at 5.527. All four factors could explain the variance of the variables at 60.418.

Table 4. KMO and bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.827
Bartlett's Test of Sphericity	**Approx. Chi-Square**	4793.756
	Df	231
	Sig.	.000

Table 5. Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%
1	8.800	40.002	40.002	8.800	40.002	40.002	4.457	20.257	20.257
2	1.852	8.417	48.419	1.852	8.417	48.419	3.486	15.845	36.102
3	1.364	6.202	54.621	1.364	6.202	54.621	3.199	14.540	50.642
4	1.216	5.527	60.148	1.216	5.527	60.148	2.091	9.506	60.148
5	1.190	5.407	65.555						
6	1.047	4.758	70.313						
7	.932	4.235	74.548						
8	.818	3.717	78.265						
9	.680	3.091	81.356						
10	.650	2.954	84.310						
11	.552	2.508	86.818						
12	.499	2.267	89.085						
13	.451	2.050	91.136						
14	.394	1.790	92.925						
15	.312	1.420	94.345						
16	.252	1.148	95.492						
17	.241	1.097	96.589						
18	.213	.966	97.555						
19	.180	.818	98.373						
20	.152	.691	99.064						
21	.120	.544	99.608						
22	.086	.392	100.000						

Table 6. Loading of factor rotation by varimax, with factor loading ≥ 0.61

Code	List of Items	Total Population (n=345)				
		Component				Cronbach's Alpha
	Local Materials: Factor 1	**F/01**	**F/02**	**F/03**	**F/04**	
A15	The cloth from bamboo fiber contains suitable weight for production into clothes.	.744				.916
A14	The cloth from bamboo fiber contains suitable weight for production into textile products.	.706				.915
A13	The bamboo fiber production process can reduce environmental effects.	.679				.915
A12	Using bamboo fiber can reduce reliance on synthetic materials.	.670				.913
	Green Products: Factor 2	**F/01**	**F/02**	**F/03**	**F/04**	
A21	The cloth from bamboo fiber is suitable for production into hats.		.784			.914
A19	The cloth from bamboo fiber can be processed into various renewable products.		.750			.915
A11	The cloth from bamboo fiber is suitable for production into woven clothing.		.748			.918
A20	The cloth from bamboo fiber is suitable for production into shoes.		.638			.916
	Healthiness: Factor 3	**F/01**	**F/02**	**F/03**	**F/04**	
A06	Textile products from bamboo fiber can protect against UV.			.878		.915
A07	Textile products from bamboo fiber possess antibacterial properties, contain good ventilation, and can be worn with comfort.			.699		.914
A05	Textile products from bamboo fiber provide good quality and durability for use.			.672		.913
	Sustainability: Factor 4	**F/01**	**F/02**	**F/03**	**F/04**	
A09	Fiber production processes do not cause environmental effects.				.721	.923
A03	Products from bamboo fiber are naturally degradable.				.618	.920
A10	The production processing time is suitable.				.616	.915

Table 7. Analyzing anti-image matrices (Measures of sampling adequacy: MSA)

	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22
A01	.854[a]																					
A02	.106	.888[a]																				
A03	.234	.072	.796[a]																			
A04	.095	.158	.171	.848[a]																		
A05	.156	.168	.093	.045	.866[a]																	
A06	.035	.132	.029	.032	.337	.790[a]																
A07	.109	.074	.011	.107	.219	.376	.888[a]															
A08	.012	.025	.056	.285	.202	.134	.172	.845[a]														
A09	.092	.088	.181	.227	.181	.085	.007	.026	.588[a]													
A10	.231	.045	.003	.266	.234	.119	.166	.071	.405	.840[a]												
A11	.070	.279	.008	.200	.354	.311	.178	.16	.114	.071	.736[a]											
A12	.012	.122	.122	.049	.002	.282	.170	.104	.061	.215	.190	.862[a]										
A13	.075	.017	.192	.111	.053	.066	.074	.214	.058	.172	.115	.397	.794[a]									
A14	.047	.085	.243	.133	.140	.059	.013	.034	.172	.013	.044	.047	.319	.875[a]								
A15	.093	.034	.048	.415	.212	.191	.159	.059	.224	.254	.090	.185	.204	.318	.737[a]							
A16	.116	.131	.121	.072	.041	.120	.062	.139	.122	.182	.058	.101	.063	.008	.166	.893[a]						
A17	.050	.045	.014	-.026	.191	-.207	.042	.111	.027	.018	.130	.196	.004	.089	.040	.370	.915[a]					
A18	.109	.029	.071	.004	.368	.125	.134	.365	.189	.075	.183	.239	.193	.156	.176	.173	.263	.812[a]				
A19	.240	.145	.310	.133	.197	.231	.032	.187	.120	.038	.179	.213	.241	.034	.023	.201	.069	.585	.740[a]			
A20	.049	.251	.076	.215	.019	.421	.184	.092	.077	.132	.016	.138	.170	.083	.398	.001	.025	.126	.133	.759[a]		
A21	.102	.299	.116	.181	.027	.188	.094	.257	.122	.013	.301	.054	.167	.015	.099	.048	.115	.016	-.343	.366	.844[a]	
A22	.157	.037	.063	.063	.090	.040	.195	.115	.001	.071	.104	.009	.379	.140	.409	.015	.055	.295	.382	.325	.214	.796[a]

To conclude, the related variables of all four factors were clarified as follows. Factor 1: Local Materials consisted of A15, A14, A13, and A12. Factor 2: Green Products consisted of A21, A19, A11, and A20. Factor 3: Healthiness consisted of A06, A07, and A05. Factor 4: Sustainability consisted of A09, A03, and A10. Out of the 22 observed variables, only 14 with the highest relationships to one another were focused on. The details are presented in Table 6.

As summarized in Table 7, the assessment results of all 14 variables that were clustered into four factors were applied to analyze consumer satisfaction with regard to their needs for utilizing the new fiber to design eco-textile products.

Consumers expressed their feelings of importance toward all four factors affecting their needs for utilizing the new textile products from high to low as follows. 1) They had high satisfaction with green products ($\bar{x}$ = 4.225; S.D = 0.654), 2) high satisfaction with local materials ($\bar{x}$ = 4.072; S.D = 0.697), 3) high satisfaction with materials ($\bar{x}$ = 3.757; S.D = 0.663, and 4) moderate satisfaction with sustainability ($\bar{x}$ = 3.158; S.D = 0.707). Thus, it can be concluded that their overall satisfaction with the four factors was high ($\bar{x}$ = 3.803; S.D = 0.520), as in Table 8.

Step 2: The results of integration for the design of eco-textile products from *D. asper* fiber, namely textile products from *D. asper* fiber blended with r-PET, were applied to the design of new products based on the factors in the conceptual framework, i.e., 1) local materials, 2) green products, 3) healthiness, and 4) sustainability, in order to produce home textiles that can be used in daily life. According to Mega Trends 2024, it can be inferred that the new textile products are eco-friendly [51] and present the features in terms of simple degradability, with lower environmental effects than those caused by PET wastes [52]. The designed prototypes of the eco-textile products were presented, inspired by a minimalist style reflecting simplicity and ease of use with no need to rely on unnecessary items in daily life [53] (Figure 4).

Table 8. Consumer feelings of importance toward all four factors (n=345)

No.	Affecting Factors	$\bar{x}$	S.D.	Satisfaction Level	Priority Ranking
1	Local Materials	4.072	0.697	High	2
2	Green Products	4.225	0.654	High	1
3	Healthiness	3.757	0.663	High	3
4	Sustainability	3.158	0.707	Moderate	4
	Total	3.803	0.520	High	

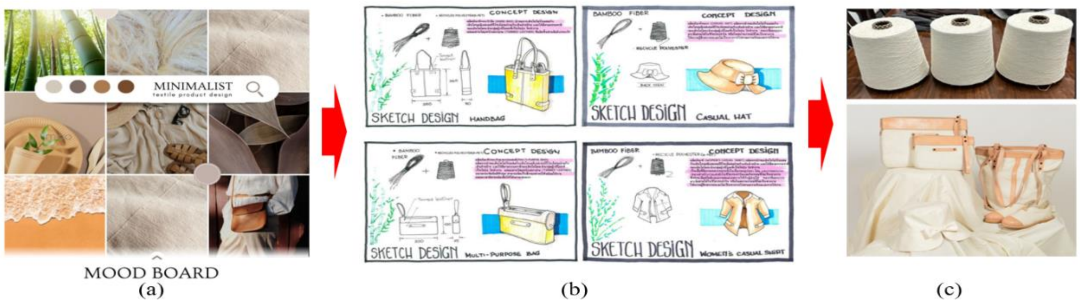


Figure 4. (a) mood board, (b) sketch design, (c) textile products

Figure 5. The prototypes of eco-textile products based on the concept of minimalism

Textiles were tailored and produced into different products for distribution of eco-textiles based on a minimalist style (Figure 5).

For the evaluation results of satisfaction with the new textile products, community enterprises that produced the new fiber mixed with polyester and processed it into the eco-cloth for producing clothing, bags, hats, and shoes distributed these products to consumers. Subsequently, data on consumer satisfaction was collected after their use (Figure 6).

According to the results in Table 9, consumers had high satisfaction with the prototypes of the textile products made from *D. asper* fiber blended with r-PET ($\bar{x}$ = 4.235; S.D. = 0.472). Their satisfaction can be arranged in order as follows according to the four factors. 1) They had a high level of satisfaction with sustainability ($\bar{x}$ = 4.407; S.D. = 0.496). 2) They had a high level of satisfaction with healthiness ($\bar{x}$ = 4.269; S.D = 0.627). 3) They had a high level of satisfaction with green products ($\bar{x}$ = 4.174; S.D. = 0.612). 4) They had a high level of satisfaction with local materials ($\bar{x}$ = 4.091; S.D. = 0.610).

Figure 6. Presentation of innovative textile products available for purchase at the Crafts Bangkok 2024 event in Thailand

Table 9. Consumer satisfaction with the prototypes of textile products from *D. asper* fiber mixed with recycled polyester

No.	Evaluated Items (n=385)	$\bar{x}$	S.D.	Satisfaction Level	Priority Ranking
	1. Local Materials				
1.1	Textile products from bamboo fiber blended with r-PET contain suitable weight to be produced into clothes.	4.181	0.743	High	
1.2	Textile products from bamboo fiber blended with r-PET contain suitable weight to be produced into textile products.	4.110	0.744	High	4
1.3	The bamboo fiber production process can reduce environmental effects.	4.289	0.663	High	
1.4	Using bamboo fiber can reduce reliance on synthetic materials.	3.785	0.718	High	
	Total	4.091	0.610	High	
	2. Green Products				
2.1	Textile products from bamboo fiber blended with r-PET are suitable for production into hats.	4.266	0.701	High	
2.2	Textile products from bamboo fiber blended with r-PET are suitable for production into eco-textile products.	4.334	0.684	High	3
2.3	Textile products from bamboo fiber blended with r-PET are suitable for production into clothing.	4.071	0.821	High	
2.4	Textile products from bamboo fiber blended with r-PET are suitable for production into shoes.	4.023	0.829	High	
	Total	4.174	0.612	High	
	3. Healthiness				
3.1	Textile products from bamboo fiber blended with r-PET can protect against UV.	4.278	0.770	High	
3.2	Textile products from bamboo fiber blended with r-PET contain antibacterial properties, provide good ventilation, and can be worn with comfort.	4.275	0.731	High	2
3.3	Textile products from bamboo fiber blended with r-PET contain good quality and durability for use.	4.255	0.605	High	
	Total	4.269	0.627	High	
	4. Sustainability				
4.1	Textile products made from bamboo fiber blended with r-PET do not cause environmental effects.	4.510	0.560	Highest	
4.2	Textile products made from bamboo fiber blended with r-PET are naturally degradable.	4.351	0.604	High	1
4.3	Textile products made from bamboo fiber blended with r-PET have a longer useful life.	4.360	0.587	High	
	Total	4.407	0.496	High	
	Total of 4 Dimensions	4.235	0.472	High	

Table 10. Relationship between the independent variables (X) and the dependent variable (Y)

Independent Variables (X)		Dependent Variable (Y)
1) Local materials, 2) green products, 3) healthiness and 4) sustainability		Consumer satisfaction with the prototypes of textile products made from *D. asper* fiber blended with r-PET.
84.7% (R Square=.847; R = .920; Adjusted R Square= .845)		

Table 11. ANOVA

Model	Sum of Squares	df	Mean Square	F	P-value
1 Regression	69.338	4	17.334	481.643	.000
Residual	12.525	348	.036		
Total	81.862	353			

Table 12. Correlation coefficient of the factors affecting consumer satisfaction

	Variables (Y)	Local Materials	Green Products	Healthiness	Sustainability
Variables (Y)	1.000	-	-	-	-
Local Materials	.746**	1.000	-	-	-
Green Products	.797**	.752**	1.000	-	-
Healthiness	.680**	.760**	.744**	1.000	-
Sustainability	.722**	.575**	.482**	.466**	1.000

Table 13. The results of stepwise multiple regression analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	P-value	Zero Order	Collinearity Statistics	
	β	Std. Error	Beta				Tolerance	VIF
1 (Constant)	.249	.097	-	2.560	.011	-	-	-
Local Materials (X1)	.154	.024	.196	6.391	.000	.746	.470	2.129
Green Products (X2)	.310	.023	.394	13.252	.000	.797	.498	2.007
Healthiness (X3)	.187	.020	.244	9.497	.000	.680	.668	1.497
Sustainability (X4)	.298	.026	.307	11.471	.000	.722	.614	1.621
R=0.920, R^2=0.847, Adj R^2=0.845, SEE=0.18971, Durbin-Watson=1.812								

** p < .01

When considering the data distribution with normality testing of all 353 data sets under evaluation of the four dimensions, i.e., 1) local materials, 2) green products, 3) healthiness, and 4) sustainability, it was considered as "normality not serious" because the data obtained contained neither too much skewness nor kurtosis to accept it due to there being > 200 data sets.

The analysis results of the relationships between the independent variables (X) and the dependent variable (Y) were as follows.

1) Residual mean was equal to 0, with normal distribution. Thus, the data was under the normal distribution line.

2) Both the independent variables and the dependent variable had linear relationships.

3) The variables had equal variance assumption. According to the scatter plot, data was arranged in a band, inclining from the left or right corner. No data cluster was found.

With regard to all four independent variables, i.e., 1) local materials, 2) green products, 3) healthiness, and 4) sustainability, parallel to the dependent variable, i.e., consumer satisfaction with the new textile products, the value of model summary test was found. More specifically, the four independent variables could predict the dependent variable at 84.7% (Table 10).

According to the analysis of variance (ANOVA), F = 481.643 and statistical significance (Sig) = .000. This implies that the multiple regression equation contained the facts as the phenomena to be studied (Table 11).

All four factors had significant relationships ($p < 0.01$), with correlation coefficients between .680–.793. The variables can be arranged in order from high to low correlation coefficient, i.e., 1) green products, 2) local materials, 3) sustainability, and 4) healthiness (Table 12).

All four factors consisted of green products (β=.310, t=13.252, P-value=.000), sustainability (β=.298, t=11.471, P-value=.000), healthiness (β=.187, t=9.497, P-value=.000), and local materials (β=.154, t=6.391, P-value=.000). They significantly affected consumer satisfaction with the prototypes of textile products made from *D. asper* fiber blended with r-PET ($p < .01$). The raw score of regression equation was $\hat{y} = .249 + .154(X_1) + .310(X_2) + .187(X_3) + .298(X_4)$. The standardized score of the regression equation was $Z = .196(X_1) + .394(X_2) + .244(X_3) + .307(X_4)$, as seen in Table 13.

Consumer satisfaction with the prototype textile products manufactured from bamboo fiber blended with recycled polyester fiber aligns with consumer priorities, particularly their primary concern for green product characteristics, specifically environmental friendliness. Bamboo is considered a renewable resource that can be cultivated and grown rapidly with low cultivation costs while producing high-performance fibers [54, 55]. Bamboo is abundant in Thailand and represents a highly sustainable alternative material that can effectively substitute synthetic fiber products. The woven fabric produced from bamboo fiber blended with recycled polyester fiber is biodegradable, thus contributing to the reduction of waste and air pollution [30].

The environmentally friendly production process aligns with carbon footprint reduction goals and enhances competitiveness in the circular economy, following the global environmental conservation trends throughout the 21st century [56]. The research outcomes serve as a prototype model that bridges sustainable innovation between the fashion textile industry and consumer demands in the green market. This supports the reduction of greenhouse gas emissions into the atmosphere, all contributing to creating a more sustainable future for global society.

5. DISCUSSION

5.1 Evaluation of antibacterial properties and distinct characteristics of woven fabric from bamboo fiber blended with r-PET

According to antibacterial property testing using

Staphylococcus aureus in bamboo fiber blended with r-PET, it was found that this property was low because young bamboo was used in this research and therefore, the amount of lignin was low. Also, chemical extraction resulted in elimination of lignin. For this reason, the antibacterial property was lower. However, using this method, white and soft bamboo fiber was obtained [47, 48]. When bamboo fiber was spun and blended with r-PET as weft yarn, followed by spinning and mixing the new yarn with cotton yarn as warp yarn, a unique texture of bamboo fiber was obtained. Because of these characteristics, the new fiber was suitable for textile product design as accessories rather than for clothing product design. Moreover, because the new cloth from this research contained tear strength in the warp yarn at 24.3 newtons and the weft yarn at 15.8 newtons, the subject cloth was strong and contained tear strength. Undoubtedly, it is suitable for textile product design that requires strength and durability. The cloth was categorized as a medium weight fabric because of its warp yarn density at 70 threads/inch while weft yarn density was equal to 65 threads/inch. The cloth weighed 193.5 g/m^2 and contained pilling resistance when the fabric was rubbed/scrubbed at a high level. Therefore, it can be concluded that the developed woven fabric contained physical properties that are suitable for production into textile products. Mixing bamboo fiber and recycled polyester could produce strong, durable, and elastic yarn. As a result, the fabric from the new yarn was very elastic and durable for use. The outcomes of this research produced yarn for textile production that presented sustainability and high eco-friendly properties. Therefore, this is an alternative for fiber, yarn, and eco-textile production for the textile industry as well as markets [30].

5.2 Consumer demand factors and guidelines for eco-textile design

According to the EFA analysis to identify the factors affecting consumer needs to apply to the design of eco-textiles from bamboo fiber, 22 predictor variables with the highest predictive values in four factors, i.e., 1) local materials, 2) green products, 3) healthiness, and 4) sustainability, were used. They were all derived from the assembly of 14 variables. These four factors can be generalized for fashion designers to apply this guideline efficiently in new fiber works [26, 57, 58]. All four factors will reflect consumer needs for products made from bamboo fiber mixed with recycled polyester. Therefore, these new textile products can fulfill consumer needs. Such development conforms to the sustainable fashion trend that focuses on eco-friendly expression until finally becoming one of the Mega Trends of 2025, which motivates consumers to pay attention to environmental concerns among modern textile entrepreneurs [51]. All four factors are regarded as a guideline to apply sustainable materials, support the use of degradable materials, and reduce environmental effects [52]. The concept of minimalism representing simplicity and basic shapes can be linked with "green products." To illustrate, modern textile products represent eco-friendly qualities through the materials used and their forms [53]. This conforms to the consumer needs in the world textile market.

5.3 Significance of bamboo fiber blended with r-PET for local and global sustainability

According to consumer satisfaction with textile products made from *D. asper* fiber blended with r-PET, it was found that Factor 1: Local materials, Factor 2: Green products, Factor 3: Healthiness, and Factor 4: Sustainability were all derived from the assembly of 14 variables. The effects and influences of these factors can be explained as follows.

1) Local Materials: Bamboo plants are utilized because there are a large number of them in the tropical regions, and they are widely grown throughout Thailand as well. The advantages of bamboo include 1) fast growth, 2) low cost, 3) light weight, 4) circular use, 5) biodegradability, and 6) high specifications as a renewable resource [19, 20]. Therefore, utilizing bamboo fiber for eco-textiles [59] can be promoted to farmers/agriculturists and local textile manufacturers so that they can apply bamboo fiber with sustainability. In addition, it can also support the national economy for more sustainability by developing an eco-economy from Thailand's rural communities.

2) Green Products: Designing textile products from bamboo fiber mixed with recycled polyester conforms to the concept of circular economy, which aims to reduce wastes to the minimum amount in the disposal process, and to motivate worthwhile reuse of plastic materials in accordance with the sustainability development plan of the Bio-Circular-Green (BCG) Economy Model. This model focuses on motivating the industrial sector in Thailand to apply circular production guidelines for creating eco-innovations from the abundant local natural materials in industrial production that aims to provide environmental, economic, and social sustainability [60].

3) Healthiness: The new textile products can reduce the growth of *Staphylococcus aureus*. They promote healthiness for users and bring a feeling of comfort during use; thus, users/consumers will obtain positive outcomes for their physical and mental health. Bamboo fiber basically provides efficient ventilation and moisture absorption. These beneficial properties of the new textile products conform to the eco-friendly concept that consistently leads to positive outcomes for consumers, the environment, society, and the economy [61]. The new textile products developed from this research give precedence to health parallel to environmental as well as economic sustainability.

4) Sustainability: The textile products made from bamboo fiber mixed with recycled polyester are useful for bringing sustainability to the textile industry and green economy for parallel development [62]. The newly developed woven fabric will help with the conservation of natural resources. Eco-innovation development by improving the body of knowledge regarding the use of local resources together with the folk wisdom of fabric weaving in Thailand's rural communities is an essential element to create income and occupational security for the local inhabitants, conforming to the concept of sustainable development [60].

Therefore, the development of bamboo fiber blended with r-PET for textile products helps bring a balance between effectively fulfilling human needs and environmental conservation at the same time. The key purpose is to provide sustainability and a better quality of life. The results of this research will encourage textile product entrepreneurs to apply available local materials for yarn production. As a result, there will be textile products with reasonable prices for consumers. Moreover, the small and medium-sized textile enterprises will be able to properly use bamboo fiber with high eco-friendly qualities, and local resources will be promoted for use as circular materials in communities. These results all conform to the goal of global sustainability, along with a sustainable economy with environmental concerns. They can also be regarded as the strategies for strengthening communities and bringing opportunities for a sustainable grassroots economy.

The development of new textile products in this research aligns with the United Nations Sustainable Development Goals (SDGs) in multiple dimensions. The research demonstrates alignment with SDG 11 (Sustainable Cities and Communities) through the promotion of local raw material usage, specifically bamboo, which enhances community sustainability. In terms of SDG 12 (Responsible Consumption and Production), the research incorporates recycled polyester and environmentally friendly raw materials. The study also addresses SDG 13 (Climate Action) by reducing greenhouse gas emissions in the textile production process.

Furthermore, the research corresponds to SDG 8 (Decent Work and Economic Growth) by creating economic opportunities for local communities, and SDG 9 (Industry, Innovation and Infrastructure) through the development of environmentally friendly textile innovations [63]. The integration of these SDGs into the development of textile products from bamboo fibers and recycled polyester responds to both domestic and global market demands, aligning with the significant increase in global market demand for environmentally friendly textile products [64].

6. CONCLUSIONS

The results of testing the properties of the new woven fabric revealed the following, i.e., low antibacterial property against *Staphylococcus aureus*, 2) white and soft bamboo fiber, 3) a rough texture of the yarn as its unique characteristic from *D. asper* fiber mixed with recycled polyester under the ratio of 30:70, and 4) the woven fabric from the new yarn possesses durability and unique characteristics from the fiber.

According to the results of designing the new textile products, four factors were required, i.e., green products, local materials, materials, and sustainability. These can facilitate other designers who intend to use bamboo fiber mixed with recycled polyester for designing new forms and styles of eco-textile products.

According to the results of consumer satisfaction with the new textile products, consumers had high satisfaction, arranged from high to low, i.e., sustainability, healthiness, green products, and local materials. When the results were applied to analysis of the relationships of the four factors, consumer satisfaction could be explained at 84.7%. The designed new textile products in this research can support further development of eco-textile products from eco-materials in Thailand and worldwide. The research also suggests the sustainable development guideline by introducing a circular production process of *D. asper* fiber mixed with recycled polyester. The final results of this research can help to develop sustainability in Thailand's rural communities in terms of a sustainable economy, eco-friendly qualities, and occupational security.

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NOMENCLATURE

D.asper	*Dendrocalamus asper*
PET	Polyethylene Terephthalate
r-PET	recycled polyester
EFA	Exploratory Factor Analysis